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DEVELOPMENT OF THE FLAMINATOR

Research and Development Technical Report USNRDL-TR-151
NS 086-001

16 January 1957

by

R.H. Heiskell
R.C. Barry

U.S. NAVAL RADIOLOGICAL DEFENSE LABORATORY
San Francisco 24, California

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ABSTRACT

A laboratory model surface removal tool was constructed which combined a flame treating burner with a rotary wire brush. Tests were conducted with this unit (identified as a Flaminator) on various types of both contaminated and uncontaminated samples to establish specifications for the various components.

A completely portable experimental field Flaminator was constructed to meet these specifications and for evaluation at a nuclear weapons proving ground.

SUMMARY

The Problem

The purpose of the present work is to develop a machine which combines flame treating and surface removal in a single unit for decontaminating porous surfaces.

Findings

Various commercial units were tested as possible components of such a machine. The most satisfactory units were selected and combined into a working model.

ADMINISTRATIVE INFORMATION

This work was carried out during the period January to November 1951 under the sponsorship of Bureau of Ships, Project No. NS 086-001, Subtask 1.4, Technical Objective AW-5c, as described in DD Form 613, dated 1 May 1952.

The Flaminator was devised for use in the recovery of concrete, asphaltic concrete, and wooden surfaces, contaminated by fallout from a nuclear detonation. Results of subsequent tests[3-6] indicate that the flame treating method of decontamination is impractical for military recovery operations. However, peacetime application of nuclear fission may present many decontamination problems which are quite different from those encountered in the recovery of military installations. Flame treating may be useful in some of the peacetime recovery operations. It is in this light that the report is now published.

Acknowledgments

The authors are grateful to R.J. Crew, J.D. Sartor, and N.J. Vella for their assistance in the tests conducted at NRDL. They also thank Roy Zimmer of the Victor Equipment Company, San Francisco, for his helpful suggestions and aid in the design of an oxy-propane burner from standard equipment and the loan of various types of burners.

1. Introduction

It was observed that an oxy-acetylene flame, used in metal cutting aboard the USS INDEPENDENCE after its return from Operation CROSSROADS, caused the surrounding atmosphere to become contaminated. Preliminary investigations of flame treating contaminated wood samples indicated that the radioactivity was carried away by volatilized material or the smoke particles. Flame treatment was first used in an actual decontamination operation on the bare concrete floor surfaces of Bldg. 223 of the Treasure Island Damage Control School following a radium spill on 18 January 1950. Liquid cleaning methods were ineffective on these surfaces but burning or dehydrating reduced the radioactivity by 15 to 50 per cent of the original count(1). The count was reduced to background when the burning was followed by hand wire brushing.

Flame cleaning is essentially a surface removal method of decontamination particularly when followed by wire brushing because such brushing actually removes a layer of the surface. The equipment used in flame treating the floors of Bldg. 223 consisted of a 4-in. oxy-acetylene descaling nozzle, a collection hood connected to a vacuum cleaner and a hand wire brush. The degree of decontamination effectiveness attained with these separate pieces of equipment suggested that they should be incorporated into a single device. This device was later named a Flaminator (Flam/e + Decontam/inator).

1.1 Objectives

The purpose of this investigation was three-fold: first, to develop and test an experimental Flaminator for use on samples approximately 1 sq ft in area; second, to ascertain the airborne hazard created by the combination of flame treating and brushing a surface; and ... to incorporate the tested features of the Laboratory Flaminator into an experimental model suitable for field scale operations.

Design of the Laboratory Flaminator

The experimental Laboratory Flaminator consists of two components ... removal head and a vacuum pick-up unit. A burner and a ... diameter wire brush mounted in a vacuum hood as shown in Fig. ... the surface removal head. The burner was a 4-in. oxy-acetylene ... nozzle which was adjustable to different heights above the test surface and at a 90°, 45°, 30° or 15° position in either the forward or backward directions. The brush mount was originally designed to float inside the hood with the weight of the driving motor resting entirely on the brush. This design was later modified by securing the motor to the hood and ...ing a single caster to a spring mount at the rear. Adjustment on this spring mount permitted variation in the load on the brush. The amount of air which entered the vacuum hood was controlled by regulating the clearance between the hood and the test surface. The vacuum hood was divided into two compartments, one for the burner and one for the brush. Initially a 1-1/2-in. vacuum line was connected to each compartment but this was replaced with 3-in. lines fitted with Butterfly valves to regulate the air flow to each compartment (Fig. 2).

The vacuum pick-up unit was an industrial type vacuum cleaner* which was modified for the insertion of a filter** between the collection

* Manufactured ... Sturtevant ... Type M-6

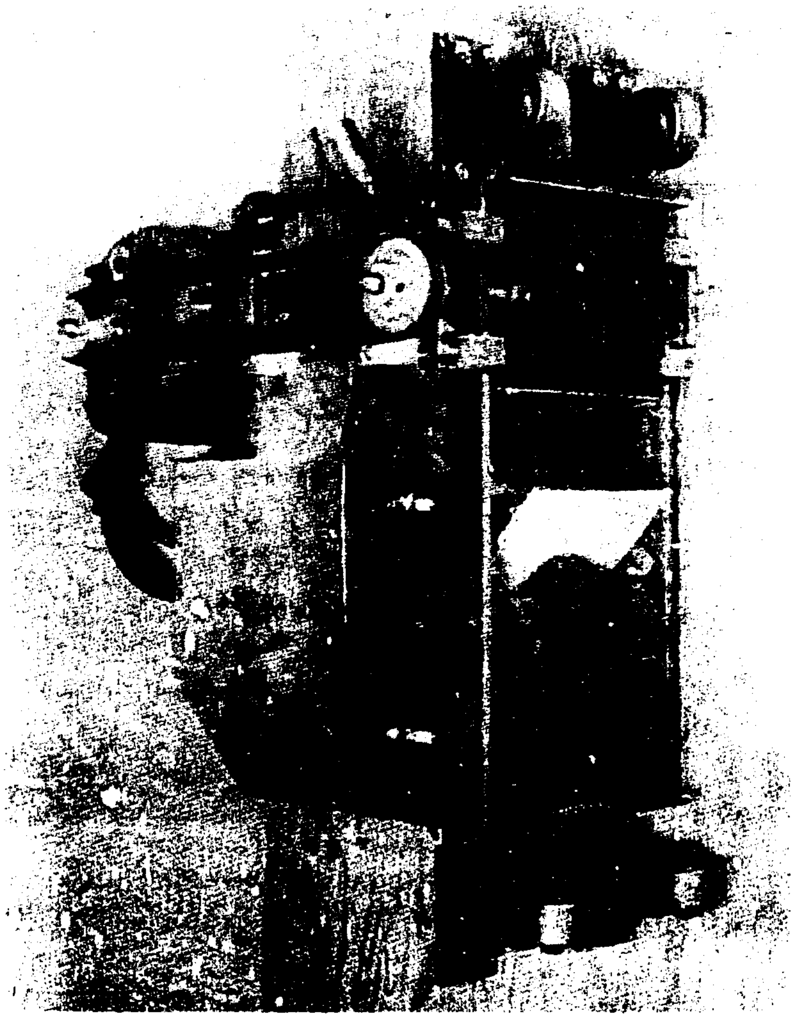

Fig. 1 Laboratory Flaminator Surface Removal Head

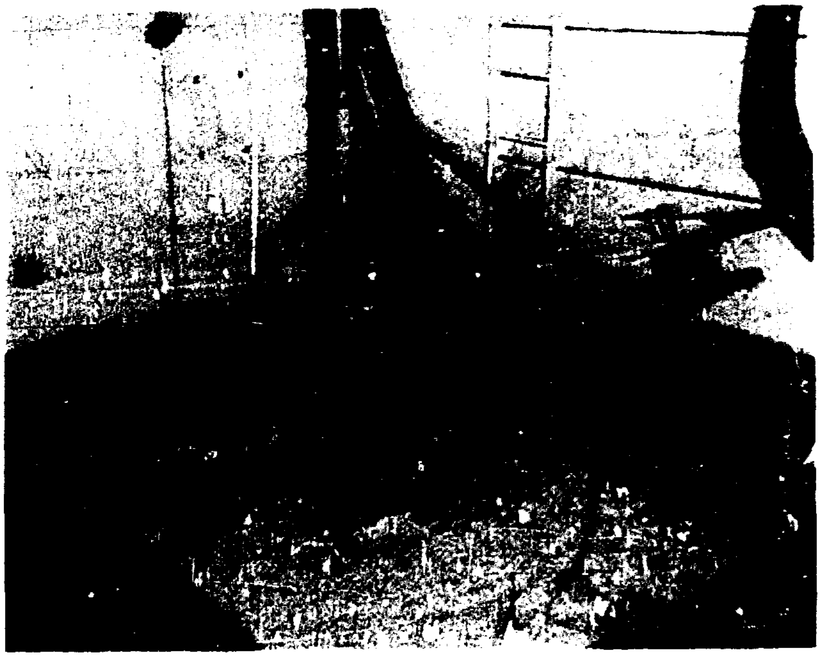

Fig. 2 Laboratory Flaminator in Operation

tank and blower as shown in Fig. 3. This vacuum cleaner had a capacity of 150 to 250 cfm of free air and drew 5 in. of Hg in a closed system. The dust collector was a canvas bag inverted in a cylindrical tank. The vacuum unit was connected to the surface removal head with 12 ft of 3-in. flexible hose.

2.1 Burner Evaluation

In all decontamination operations, the speed of operation is a prime consideration. The speed of operating the Flaminator is mainly dependent upon the efficiency of the burner, so a study was made to determine what type burner would be most satisfactory. In the selection of the

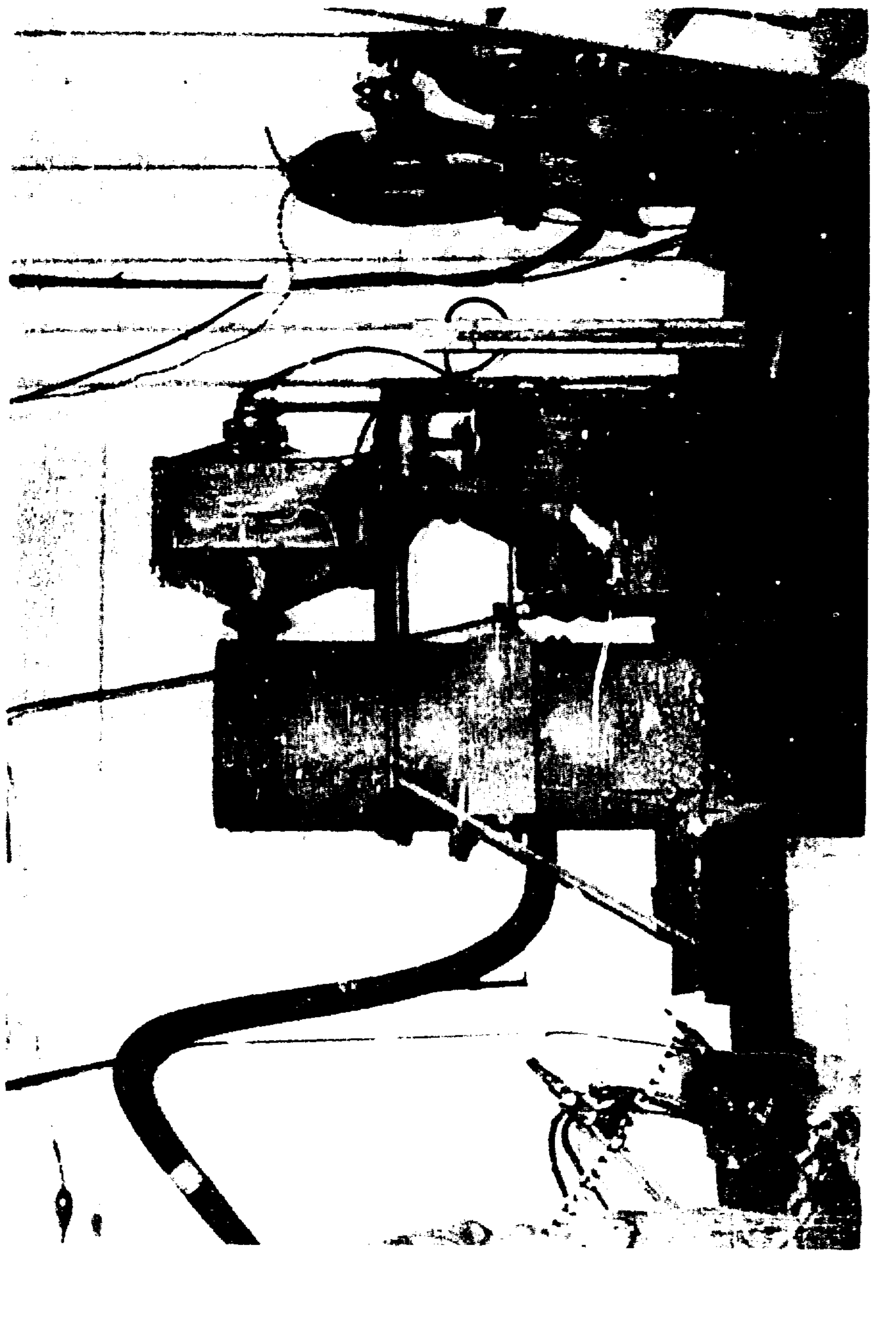

Fig. 3 Vacuum Pickup Unit of Laboratory Flaminator

most efficient fuel and burner for use in the Flaminator the following properties were considered:

(a) Maximum flame temperature and calorific value

(b) High flame propagation rate, thus permitting rapid fuel consumption and high Btu output

(c) High velocity flame to give a sweeping action which would remove loose radioactive particles from the surface.

Table 1 lists a number of commercially available fuels together with their essential characteristics. The calorific value of all the hydrocarbons listed are very nearly the same, with the exception of hydrogen. Hydrogen was not considered for use in the Flaminator because there are no suitable commercial burners and it is very hazardous. Acetylene has the highest flame temperature of the fuels listed and many commercial burners are readily available. Another important property to be considered in the design of portable equipment is the weight of storage tanks and space requirements. Acetylene is dissolved in acetone under relatively low pressures. The entire contents of the storage tanks can not be used because of the danger of drawing off acetone. This fact makes it necessary to manifold several acetylene cylinders to maintain the same high fuel consumption that could be handled by a single cylinder of liquid petroleum gas, such as propane, which is compressed at high pressures. Thus despite the 10 per cent lower flame temperature which the table indicates for propane, this fuel appears highly practical for the burner of a portable Flaminator.

2.1.1 Qualitative Burner Tests

Qualitative tests were made on the various burners listed in Table

TABLE 1 Characteristics of Burner Fuels

Fuel	Btu/lb	OXYGEN MIXTURE: Temperature: Ignition °F	OXYGEN MIXTURE: Temperature: Flame °F	OXYGEN MIXTURE: Inflammability % Fuel: Low	OXYGEN MIXTURE: Inflammability % Fuel: High	AIR MIXTURE: Temperature: Ignition °F	AIR MIXTURE: Temperature: Flame °F	AIR MIXTURE: Inflammability % Fuel: Low	AIR MIXTURE: Inflammability % Fuel: High	Flame Velocity (ft/sec)
1. Hydrogen	60,810	1076-1094	4622	4 to	94	1076-1094	3630	4.1	74	2 to 8
2. Methane	23,550	1033-1292	5300			1202-1382	3600	5.3	14	
3. Propane	21,564	914-1058	5250	4.1 to	50		3497	2.4	9.5	1.5
4. Butane	21,247		5250				3500	1.85	8.4	1.5
5. Acetylene	21,572	781- 824	5850			763- 824	4217	2.5	80	4.7
6. Gasoline	20,700	396				865		1.4	6.5	
7. Kerosene	20,200	563				518	2000			
8. Aluminum	13,35[illegible]		5500							
9. Magnesium	10,680									
10. Carbon	14,180		4082				3820[a]			

(a) C to CO_2

2 by observing their effectiveness in charring wood, softening asphalt or spalling concrete. The gas consumption or flow rates during these tests were determined with a "Florator", calibrated for acetylene or propane and oxygen or compressed air. All of the burners are standard production units with the exception of No. 10. The Victor Equipment Company made this burner by modification of a standard oxy-acetylene descaling nozzle. The flame orifices were counterbored to a depth of 1/16 in. to insure propagation of the lower velocity oxy-propane flame.

Four burners, Nos. 6, 8, 9 and 10 of Table 2, were chosen for the subsequent quantitative burner tests. Burners No. 6 and 8 were the most satisfactory of the Bunsen type (induced-air) burners tested. The principal advantage of this type burner for the Flaminator is that it eliminates the necessity of carrying oxygen cylinders. Burner No. 6 (an acetylene burner) produced a medium temperature, low-velocity 2-in. flame. The chief disadvantage of this burner is its low heat output. It gave satisfactory charring of wood and softened asphalt, but did not produce concrete spalling. Burner No. 8 (a propane burner) produced a medium temperature, low velocity round flame with a very long inner cone. The flame tended to flare out on contact with a surface so that its heat transfer efficiency was poorer than many of the other burners. The large heat output of this burner gave good charring of wood and softening of asphalt, but was insufficient to spall concrete. The oxy-acetylene burner No. 9 was chosen because of its high temperature, high velocity flame and efficient operation. It was similar to Burners No. 4 and No. 5, in operation, but it was cheaper and more readily available. An obvious advantage of the oxy-propane burner, No. 10, was its ease in lighting and apparent wide inflammability

TABLE 2 Qualitative Test of Burners

Manufacturer	Burner No.	Name	Model No.	Size Burner	FUELS Type	FUELS Rates	FUELS Air-O_2	FLAME Type of Flame	FLAME Temp	Attachments for Operation	Remarks on Operation
Aeroil Prod. Co.	1	Aeroil "Giant"	99	4" dia	Kerosene	1-1/2 gal/hr	Air-Ind	Round-long	2000°F	Supplied with 5-gal pressure fuel tank	Burns kerosene, coal oil, range oil stove oil, furnace oil.
Aeroil Prod. Co.	2	Aeroil "Senior"	99	3" dia	Kerosene	1 gal/hr	Air-Ind	Round-long	2000°F	Supplied with 4-gal pressure fuel tank	Burns kerosene, coal oil, range oil, stove oil, furnace oil.
Aeroil Prod. Co.	3	Aeroil "Junior"	99	2" dia	Kerosene	3/4 gal/hr	Air-Ind	Round-long	2000°F	Supplied with 2-gal pressure fuel tank	Must be pr[illegible] and pre-heated like blow torch [illegible]fore operation. Tested on [illegible]alt.
Air Reduction Co. "Airco"	4	Flat Descaling tip assembly	120	12" wide	Acetylene	240 cu ft/hr	O_2	High velocity ribbon	5800°F	Requires extension tube, mixer and blow pipe	Available in sizes 4" to 14" in 2" increments. Not tested. This burner is used to descale the Golden Gate Bridge.
The Linde Air Products Co. "Oxweld"	5	Multiflame In-line Heating Head		4" wide	Acetylene	90 cu ft/hr	O_2	High velocity ribbon	5800°F	Requires extension, mixer, blowpipe and stride	Available in 1,2,3,4,6,8 and 10" widths; 4" model demonstrated; worked well on concrete.
The Linde Air Products Co. "Oxweld"	6	Prest-O-Light Paint Burning stem	9	2" wide	Acetylene	Not detectible on flow meters	Air-Ind	Low velocity flat	4200°F	Requires No. 3 handle with needle valve	Produces a flat solid flame with an inner cone from 1/16" to 1/2" long. Tested on wood and asphalt. Two burners manifolded for subsequent test on Flamimeter.
The Linde Air Products Co. "Oxweld"	7	Sand Jet Piercing Blowpipe		1-1/4" dia	Kerosene		O_2	High velocity water jet, 6000 ft/sec	4300°F	Requires truck to carry kerosene, oxygen and water	Used to pierce holes in rock 5 to 9 ft deep in about 10 min; reviewed in Mining Engineering July '51.
Purity Cylinder Gases, 374 E. Division Ave. Grand Rapids 3, Michigan	8	"Vulcan"	5	1" dia	Propane	5 to 60 cu ft/hr	Air-Ind	Low velocity, round-long flame. No inner cone	3500°F	Requires handle with needle valve	Available in smaller burners as No. 1,2,4 and as a paint burner No. 3. Selected for subsequent Flamimeter burn tests.
Victor Equipment Co. San Francisco	9	Ribbon Type Flame Descaling nozzle	361	4" wide	Acetylene	42 to 90 cu ft/hr	O_2	High velocity ribbon	5800°F	Requires welding blow-pipe or both	Used in Treasure Island decontamination operation. Selected for additional Laboratory tests. Also available in 6" width - Model #462.
	10	Special Ribbon Type Flame Descaling Nozzle	361P	4" wide	Propane	12 to 30 cu ft/hr	O_2	High velocity ribbon	5200°F	Requires welding blow-pipe or both	A modified No. 361 burner. Selected for subsequent Flamimeter tests.
	11	Hansen Type Burner	9800	1/4" dia 1/2" dia	Acetylene Propane	Not detectible on flow meters	Air-Ind	Low velocity round	4400°F 3500°F	Requires only one gas supply	Available with tips with various size orifices. No. 601, 602, 604, 610 for acetylene; 621, 622 for propane. One acetylene and one propane tip tested on wood and concrete. Heat output too low for flame treating concrete.

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range. Qualitatively, the oxy-acetylene and oxy-propane burners appeared equally efficient in flame treating wood, asphalt, and concrete.

2.1.2 Quantitative Burner Tests

Three quantitative tests were conducted on the selected burners.

(a) Determination of maximum temperature produced when enclosed in the moving Flaminator.

(b) Determine the optimum gas rates of the oxy-propane burner by noting the time required to heat a steel block through a specified temperature range.

(c) Determine the relative effectiveness of the burners under various conditions by comparison of degree of wood charring.

(a) Temperature Tests

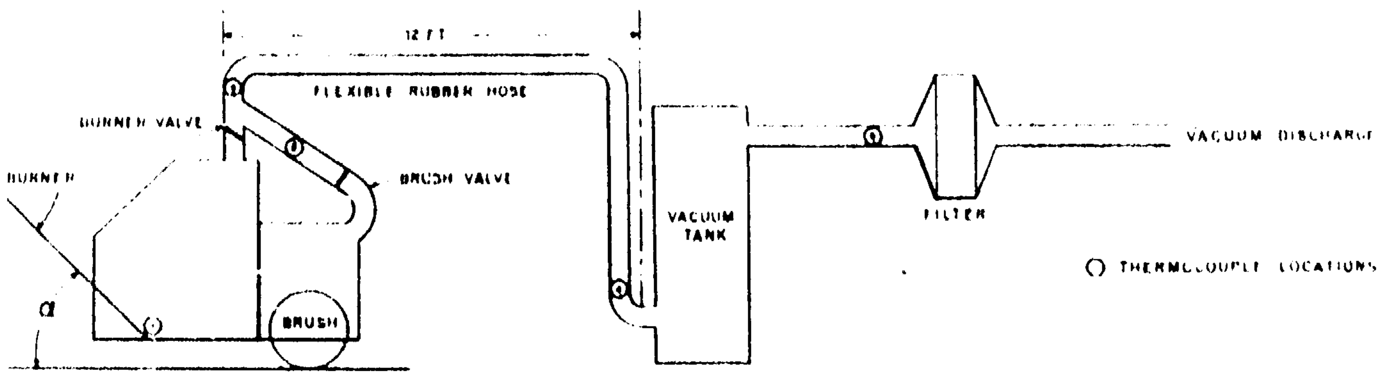
The Flaminator, fitted with various burners adjusted at various angles and heights, was run back and forth across a wood surface 4 ft by 8 ft until the temperatures in the hood and vacuum system reached a maximum. The brush was not used in these temperature tests. The temperatures were recorded every 30 sec until they reached a maximum and leveled off or the burner blew out. The results of the temperature tests are listed in Table 3. These tests indicated that the oxy-acetylene burner was unsatisfactory when enclosed by the hood because of the ever present danger of flash back. Although it is unlikely that the flame would blow back beyond the oxygen and acetylene mixer, the blow backs prevent consistent and reliable operation of the Flaminator.

Blow backs were apparently caused by the burner head and its pipe connections becoming hot enough to ignite the acetylene before it reached the burner tips. Thermocouple No. 1 was located in a hole bored in the

TABLE 3 Flaminator Tests

Run	Gas Rate cfm		Temperatures °F					Valves		Total Time		Burner height (in.)	Remarks
	Gas	Oxy	1	2	3	4	5	Burner	Brush	To Max. Temp.	Of Run		
					Oxy-acetylene Burner, No. 10 $\gamma = 90^{\circ}$								
8	-	-	650	70	455	170	130	Open	Closed	-	1'15"	3/16"	Blow Back
9	-	-	610	70	392	236	207	Open	Closed	-	3'0"	3/8	Blow Back
10	-	-	610	70	375	232	200	Open	Closed	-	2'45"	3/8	Blow Back
11	-	-	390	70	455	260	238	Open	Closed	7'0"	9'0"	9/16	
12	-	-	430	100	330	278	248	Open	Open	4'0"	8'30"	9/16	
					Oxy-acetylene Burner, No. 10 $\gamma = 45^{\circ}$								
13	0.67	0.65	632	67	279	215	200	Open	Closed	7'0"	25'0"	1/8	
14	0.80	0.65	510	67	341	250	238	Open	Closed	8'0"	10'0"	(a)	
15	1.03	1.0	705	628	405	310	268	Open	Closed	9'0"	10'0"	(a)	Long Flame
16	1.28	1.28	785	822	399	300	260	Open	Closed	-	5'0"	(a)	Long Flame
17	0.66	0.62	620	67	334	235	215	Open	Closed	15'0"	20'0"	1/32	
18	0.62	0.62	555	-	360	262	232	Open	Closed	7'0"	21'40"	1/32	Burner Dragging
19	0.80	0.85	636	67	410	276	240	Open	Closed	-	6'0"	1/32	Blow Back/Burner Dragging
21	0.80	0.85	564	-	340	282	245	Open	Closed	13'20"	15'0"	1/8	
26	0.62	0.65	563	80	350	197	162	Open	Closed	15'0"	17'0"	1/16	
27	0.62	0.65	692	236	245	155	135	Closed	Open	-	3'0"	1/16	Blow Back
					Acetylene-induced Air Burner, No. 6 $\gamma = 85^{\circ}$								
20	0.37	-	-	101	120	125	116	Open	Closed	28'0"	30'0"	1/4	
					Oxy-propane Burner, No. 11 $\gamma = 45^{\circ}$								
22	0.45	1.40	1015	383	400	194	151	Closed	Open	10'0"	10'0"	1/16	
23	0.45	1.40	650	101	380	203	163	Open	Closed	13'0"	15'0"	1/16	
24	0.35	1.10	735	67	340	180	150	Open	Closed	15'0"	18'0"	1/16	
25	0.35	1.10	1049	334	340	182	155	Closed	Open	12'0"	15'0"	1/16	

(a) Burner tip touching floor.



burner head and provided an indication of the temperature rise, but it was not properly located to give the maximum temperature of the burner head. The burner head was heated more rapidly when it was close to the floor. At a height of 3/16 to 3/8 in. above the floor, blow back occurred after only 1 to 3 min (Runs TT-8, TT-9 and TT-10; Table 3), and thermocouple No. 1 reached a temperature of 600 to 650°F. When the burner was raised to a height of 9/16" no blow back occurred and 7 min were required for the burner head to reach its maximum temperature of 390°F (Run TT-11). The burner head reached a temperature of 705 and 785°F respectively without blow backs occurring in TT-15 and TT-16. In these two tests the high gas rates gave a very long flame that was drawn back into the brush compartment and did not "leak" back and heat the gas line as happened with a short flame. In the case of the short flame the burner radiator (cooling section joining the burner head to the line) and gas lines were heated to a high temperature by direct contact with the flame. The oxy-acetylene burner was less susceptable to blow backs when mounted in the 45° position (Fig. 4). Under such condition the flame was pulled along the surface by the combined action of the moving Flaminator and the vacuum.

The oxy-propane burner was far superior to the oxy-acetylene burner because there was no danger of blow backs and the difference in their flame temperatures as presented in Table 1 is believed to be insignificant. The burner head temperatures in Run TT-22 and TT-23 were 1015 and 1040°F respectively without blow backs occurring. No other major problem evolved as a consequence of enclosing the oxy-propane burner inside the vacuum head.

The wire brush was soon damaged by direct contact with the flame

Fig. 4 Underneath view of Flaminator with burner mounted at 45° angle (shows vacuum drawing flame into Burner Compartment, but away from Brush).

but this could be remedied by increasing the distance between the burner and brush. The maximum temperature of 455° F maintained at the vacuum hood outlet (Thermocouple No. 3) indicated that a metal flexible hose was needed in place of the rubber one. Also the temperature of the gases entering the filter (Thermocouple No. 5) exceeded the values recommended for this type of filter.

(b) Optimum Ratio of Oxygen to Propane

In the determination of the optimum gas rates for the oxy-propane burner, it was mounted in a fixed position above a steel block (1/2 in. by 2 in. by 5 in.) into which was embedied a chromelalumel thermocouple. The propane rate was adjusted to a given value and the oxygen rate was varied over a wide range. The time to heat the block from 520 to 1595° F was noted for each oxygen rate. The propane rate was changed and the process repeated until the propane rate had been varied within maximum and minimum limits. The results of these tests are presented in Table 4 and Fig. 5.

TABLE 4 Oxygen/Propane Ratios

OXYGEN/PROPANE RATIO	FLOW RATE (cfm)	Time to heat sample from 520 to 1595°F (sec)
3.10	0.482	84.
3.70	0.482	62.5
3.90	0.482	63.
3.60	0.386	73.
4.12	0.386	69.
4.40	0.386	71.5
4.70	0.386	81.
3.10	0.322	104.
3.70	0.322	81.
4.40	0.322	74.5
4.65	0.322	79.5
3.10	0.258	122.
3.90	0.258	90.5
4.30	0.258	88.
4.70	0.258	84.5
5.00	0.258	82.5
5.40	0.258	98.
3.10	0.193	160.
4.10	0.193	118.
4.70	0.193	114.
5.20	0.193	123.

The minimum time required to heat the steel block through the given temperature range is a measure of the efficiency of the flame. The oxygen-to-propane ratio required for this minimum heating time is the

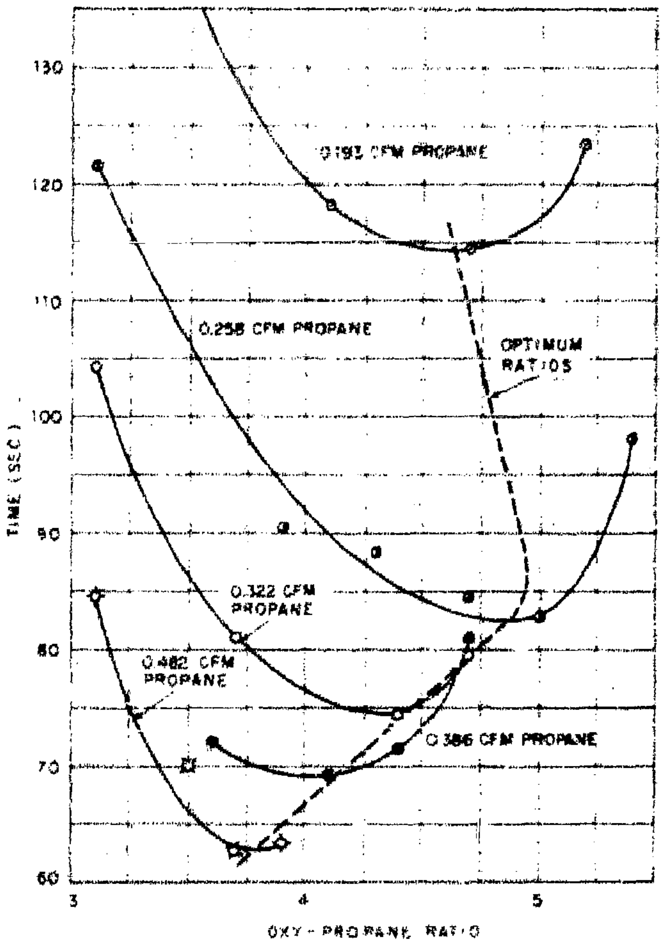


Fig. 5 Oxy-propane Ratio vs Time to Heat Sample from 520 to 1595°F. Burner: 4-in. ribbon flame descaling unit.

optimum gas rate for the oxy-propane burner.

(c) Burner Effectiveness Under Various Conditions

Wood charring standards were prepared with the Flaminator equipped with the oxy-acetylene burner mounted at a 45° angle, 1/16 in. above the surface of the sample and consuming oxygen at a rate of 0.65 cfm. The Flaminator was run across four wood samples at each of the following approximate speeds: 0.60, 0.30, 0.15, and 0.08 ft/sec. The degree of charring on each of the samples was arbitrarily designated as charring indices 1, 2, 3 and 4. These charring indices are shown in Fig. 6.

0 1 2 3 4

CHARRING INDICES

Fig. 6 Wood Charring Indices

Wood charring tests were made with the oxy-acetylene, oxy-propane, acetylene-induced air, and propane-induced air burners adjusted to different heights, and at different angles and using different gas rates. The degree of charring on the sample was compared to the four standards, visually, by three investigators. A degree of charring that fell between two standards was estimated to the nearest 1/10 point. The degree of charring is a measure of the effectiveness of flame treating wood surfaces and depends upon such factors as the speed of operating the Flaminator, heat output of the burner, position of the burner relative to the surface being treated and the vacuum being applied to the collecting hood. The results of the charring tests are arranged in Tables 5, 6, 7, and 8 for quick comparison of the effects of the variables.

The speed of operating the Flaminator and the heat output of the burner affected the degree of charring more than any of the other variables considered. It is desirable to operate the Flaminator at the highest possible rate that gives the most effective charring; however, the operating speed is limited by the maximum useable heat output of the burner. Table 5 shows that the height of the burner above the surface does not affect the charring as much when the burner is in the 90° position as when it is in the 45° position. At the higher gas rates, where the heat output is greater, the height of the burner above the surface did not influence the charring as much as it did with the lower gas rates. The heat output of the burner must be held within definite limits to avoid excessive heating of the Flaminator parts, the vacuum system and filter. Table 6 indicates that the degree of charring is directly proportional to the BTU output of the burner. Table 7 shows that the degree of charring

TABLE 5 Effect of Burner Height on Wood Charring

Sample	Burner Height (in)	Burner	Burner Angle	Flaminator Speed (ft/sec)	Theoretical Heating Rate (Btu/hr)	Charring Index
Std A	1/16	Oxy-Acetylene	45°	0.08	54,500	4.0
CT 12	3/16					3.6
CT 44	1/16	Oxy-Propane	45°	0.08	68,400	4.0
67	1/8					4.0
56	3/16					3.7
CT 52	1/16	Oxy-Propane	45°	0.08	24,300	2.8
53	3/16					0.0
Std B	1/16	Oxy-Acetylene	45°	0.15	54,500	3.0
CT 11	3/16					2.5
CT 19	1/16	Oxy-Acetylene	90°	0.15	54,500	3.0
14	1/8					3.0
20	3/16					3.0
CT 33	1/16	Oxy-Propane	90°	0.15	69,900	3.5
36	3/16					3.8
CT 3	1/16	Oxy-Acetylene	45°	0.15	70,400	3.8
6	3/16					3.5
Std C	1/16	Oxy-Acetylene	45°	0.30	54,500	2.0
CT 10	3/16					1.3
CT 18	1/16	Oxy-Acetylene	90°	0.30	54,500	2.4
15	1/8					2.2
21	3/16					2.0
CT 29	1/16	Oxy-Propane	90°	0.30	53,200	2.2
40	3/16				51,700	2.0
CT 43	1/16	Oxy-Propane	45°	0.30	68,400	2.0
65	1/8					2.2
57	3/16					1.5
CT 48	1/16	Oxy-Propane	45°	0.30	51,700	1.7
69	1/8					1.4
CT 62	1/8	Oxy-Propane	45°	0.30	97,200	3.0
58	3/16					2.5
Std D	1/16	Oxy-Acetylene	45°	0.60	54,500	1.0
CT 9	3/16					1.3
CT 1	1/16	Oxy-Acetylene	45°	0.60	70,400	1.7
8	3/16					1.5
CT 17	1/16	Oxy-Acetylene	90°	0.60	54,500	1.5
16	1/8					1.3
22	3/16					1.2
CT 30	1/16	Oxy-Propane	90°	0.60	53,200	1.1
39	3/16				51,700	1.3

TABLE 6 Effect of Heating Rate and Flaminator Speed on Wood Charring

Sample		Theoretical Heating Rate (Btu/Hr)	Burner	Burner Height (in)	Burner Angle	Flaminator Speed (ft/sec)	Charring Index
CT	26	24,300	Oxy-Propane	1/16	90°	0.08	3.3
	27	53,200					4.0
	34	69,900					4 +
CT	52	24,300	Oxy-Propane	1/16	45°	0.08	2.8
	50	51,700					3.8
	44	68,400					4.0
CT	53	24,300	Oxy-Propane	3/16	45°	0.08	0.0
	54	51,700					Partial Burn
	56	68,400					3.7
Std	B	54,500	Oxy-Acetylene	1/16	45°	0.15	3.0
CT	3	70,400					3.8
CT	25	24,300	Oxy-Propane	1/16	90°	0.15	2.0
	28	53,200					3.5
	33	69,900					3.5
CT	66	68,400	Oxy-Propane	1/8	45°	0.15	3.5
	61	97,200					4 +
CT	24	23,300	Oxy-Propane	1/16	90°	0.30	1.3
	29	53,200					2.2
	32	69,900					2.0
CT	40	51,700	Oxy-Propane	3/16	90°	0.30	2.0
	37	69,900					2.8
CT	51	24,300	Oxy-Propane	1/16	45°	0.30	0.7
	48	51,700					1.7
	43	68,400					2.0
CT	57	68,400	Oxy-Propane	3/16	45°	0.30	1.5
	58	97,200					2.5
CT	69	51,700	Oxy-Propane	1/8	45°	0.30	1.4
	65	68,400					2.2
	62	97,200					3.0
CT	69	51,700	Oxy-Propane	1/8	45°	0.30	1.4
	65	68,400					2.2
Std	D	54,500	Oxy-Acetylene	1/16	45°	0.60	1.0
Ct	1	70,400					1.7
CT	9	54,500	Oxy-Acetylene	3/16	45°	0.60	1.3
	8	70,400					1.5
CT	23	23,300	Oxy-Propane	1/16	90°	0.60	0.3
	30	53,200					1.1
	31	69,900					1.1
CT	39	51,700	Oxy-Propane	3/16	90°	0.60	1.3
	38	69,900					1.8
CT	47	51,700	Oxy-Propane	1/16	45°	0.60	0.8
	46	68,400					1.5
CT	64	68,400	Oxy-Propane	1/8	45°	0.60	1.0
	63	97,200					1.8

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TABLE 7 Effect of Burner Angle on Wood Charring

Sample	Burner Angle	Burner	Burner Height (in)	Flaminator Speed (ft/sec)	Theoretical Heating Rate (Btu/Hr)	Charring Index
CT 26	90°	Oxy-Propane	1/16	0.08	24,300	3.3
52	45°				24,300	2.8
CT 27	90°	Oxy-Propane	1/16	0.08	53,200	4.0
50	45°				51,700	3.8
CT 34	90°	Oxy-Propane	1/16	0.08	69,900	4 +
44	45°				68,400	4.0
Std B	45°	Oxy-Acetylene	1/16	0.15	54,500	3.0
CT 19	90°				54,500	3.0
CT 28	90°	Oxy-Propane	1/16	0.15	53,200	3.5
49	45°				51,700	3.0
CT 33	90°	Oxy-Propane	1/16	0.15	69,900	3.5
45	45°				68,400	3.2
Std C	45°	Oxy-Acetylene	1/16	0.30	54,500	2.0
CT 18	90°				54,500	2.4
CT 10	45°	Oxy-Acetylene	3/16	0.30	54,500	1.3
21	90°				54,500	2.0
CT 29	90°	Oxy-Acetylene	1/16	0.30	53,200	2.2
48	45°				51,700	1.7
CT 32	90°	Oxy-Acetylene	1/16	0.30	69,900	2.0
43	45°				68,400	2.0
98	45°				68,400	3.5
CT 24	90°	Oxy-Propane	1/16	0.30	24,300	1.3
51	45°				24,300	0.7
CT 37	90°	Oxy-Propane	3/16	0.30	69,900	2.8
57	45°				68,400	1.5
Std D	45°	Oxy-Acetylene	1/16	0.60	54,500	1.0
CT 17	90°				54,500	1.5
CT 9	45°	Oxy-Acetylene	3/16	0.60	54,500	1.3
22	90°				54,500	1.2
CT 30	90°	Oxy-Propane	1/16	0.60	53,200	1.1
47	45°				51,700	0.8
CT 31	90°	Oxy-Propane	1/16	0.60	69,900	1.4
46	45°				68,400	1.5

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TABLE 8 Effect of Flaminator Speed on Wood Charring

Sample	Flaminator Speed (ft/sec)	Burner	Burner Height (in)	Burner Angle	Theoretical Heating Rate (Btu/Hr)	Charring Index
Std A	0.08	Oxy-Acetylene	1/16	45°	54,500	4.0
B	0.15					3.0
C	0.30					2.0
D	0.60					1.0
CT 4	0.08	Oxy-Acetylene	1/16	45°	70,400	4 +
3	0.15					3.8
2	0.30					2.6
1	0.60					1.7
CT 5	0.08	Oxy-Acetylene	3/16	45°	70,400	4 +
6	0.15					3.5
7	0.30					2.5
8	0.60					1.5
CT 12	0.08	Oxy-Acetylene	3/16	45°	54,500	3.6
11	0.15					2.5
10	0.30					1.3
9	0.60					1.3
CT 13	0.08	Oxy-Acetylene	1/8	90°	54,500	4.0
14	0.15					3.0
15	0.30					2.2
16	0.60					1.3
CT 27	0.08	Oxy-Propane	1/16	90°	53,200	4.0
28	0.15					3.5
29	0.30					2.2
30	0.60					1.1
CT 50	0.08	Oxy-Propane	1/16	45°	51,700	3.8
49	0.15					3.3
48	0.30					1.7
47	0.60					0.8
CT 90	0.08	Oxy-Propane	3/32	45°	53,200	4 +
91	0.15					3.9
92	0.30					2.7
93	0.60					1.8

was slightly less with the burner mounted at the 45° position than at the 90° position. This slight advantage in charring effectiveness is outweighed by the excessive heating of the burner and gas lines when the burner is vertically mounted.

The oxy-propane burner gave charring indices slightly less than those obtained with the oxy-acetylene burner, but the advantages previously listed for propane outweigh this slight difference. Compare Stds. A, B, C and D with CT-47, 48, 49 and 50 in Table 8.

2.2 Surface Removal Tool Tests

A rotary wire brush was chosen as the surface removal tool for the laboratory Flaminator. Tests were made on with-grain and cross-grain wood samples to determine the effect of the following variables:

Brush Construction	Type - Knot or solid fill wire brush Wire Diameters - 0.005, 0.0118, 0.014 and 0.016 in.
Brush Speed	Rotational - 1400 to 1900 rpm Linear 0.08, 0.15, and 0.30 ft/sec
Brush Loading	5 to 55 lb.

Wood samples were made up of clear selected Douglas Fir and finished to a size 1-5/8 in. by 3-5/8 in. by 12 in. Half of the samples were cut with the grain running lengthwise (with-grain samples) and half were cut or assembled from glued sections with the grain running crosswise (cross-grain samples). The samples were placed in a floor well and the Flaminator towed across them at the desired linear speed. The towing device (Fig. 7) consisted of a constant speed shaft around which the towing cable was wound. The speed of this shaft was regulated by a variable speed torque converter attached to an electric motor.

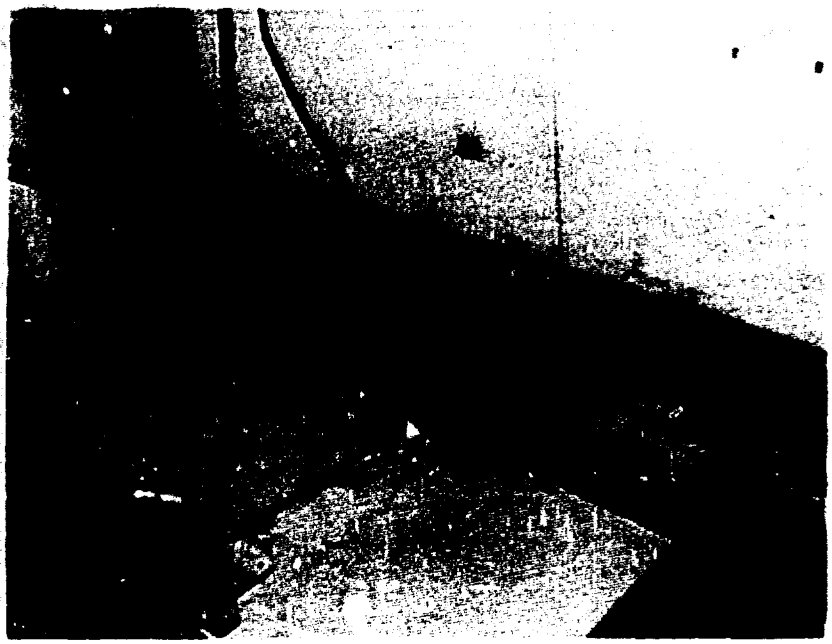


Fig. 7 Towing Device for Laboratory Flaminator

The brush loading was determined on an especially rigged platform scale. Supporting plates were secured to the sides of a standard platform scale so that the wheels of the Flaminator were in the same plane as the platform with only the brush touching it. Varying the tension on the rear wheel mounting spring changed the brush loading which could be measured on the scale.

Before and after each surface removal test the thickness of the samples were measured with a surface plate and a dial indicator attached to a surface gage. Each sample was moved across the surface plate with the dial indicator point resting on the sample surface (Fig. 8).

Fig. 8 Measuring Surface Removal

A maximum and minimum reading was recorded and also an average was taken as the sample was moved under the dial indicator.

The results of the with-grain tests are presented in Table 9 and those for cross-grain tests in Table 10. The linear speed of the Flaminator affected the amount of surface removal more than any of the other variables considered. Data in Tables 9 and 10 show that 30 to 75 per cent more surface was removed when the linear speed was reduced by a factor of 2.

The effect of wire diameter is very slight in comparison with the other factors. The 0.005-in. diameter wire was the least effective

TABLE 9 With Grain Brush Tests

Run	Brush Type	Brush Speed Rotational (rpm)	Brush Speed Linear (ft/sec)	Brush Loading (lb)	Material Removed (in. x 10^{-3}) Min.	Max.	Avg.
Bt 92	0.005 wire-solid	1700	0.30	35	0	8	6
94		1700	0.08	35	2	14	5
98		1400	0.30	35	2	-	1
15	0.0118 wire-solid	1600	0.15	5	2	8	4
16		1600	0.08	5	2	12	7
100		1500	0.30	35	2	1	1
35	0.0118 wire-knot	1600	0.08	5	2	9	3
102		1500	0.30	35	1	2	2
43	0.014 wire-solid	1600	0.08	5	4	12	6
41		1600	0.30	5	2	4	3
39		1600	0.30	10	1	3	0
37		1600	0.08	10	4	12	11
82		1900	0.12	35	11	15	12
84		1600	0.12	35	4	6	5
89		1600	0.30	35	1	8	3
29	0.016 wire-knot	1600	0.08	5	3	2	2
31		1600	0.30	5	2	8	2
33		1600	0.30	10	1	1	0
104		1500	0.30	35	2	3	1

TABLE 10 Cross-grain Brush Tests

Run	Brush Type	Brush Speed Rotational (rpm)	Brush Speed Linear (ft/sec)	Brush Loading (lb)	Material Removed (in. x 10^{-3}) Min.	Max.	Avg.
BT 93	0.005 wire-solid	1700	0.30	35	2	4	3
95		1700	0.08	35	3	7	4
99		1400	0.30	35	1	2	1
14	0.0118 wire-solid	1600	0.15	5	4	16	9
17		1600	0.08	5	9	22	14
101		1400	0.30	35	3	4	5
36	0.0118 wire-knot	1600	0.08	5	10	14	8
103		1500	0.30	35	1	9	4
38	0.014 wire-solid	1600	0.08	10	11	38	19
40		1600	0,30	10	2	18	9
42		1600	0.30	5	0	7	4
44		1600	0.08	5	9	15	11
83		1900	0.12	35	7	20	14
85		1600	0.12	35	3	7	3
88		1600	0.30	35	1	4	5
30	0.016 wire-knot	1600	0.08	5	6	44	24
32		1600	0.30	5	3	6	4
34		1600	0.30	10	2	0	5
105		1500	0.30	35	5	7	9

of all the brushes tested. Although surface removal measurements obtained with this brush were about the same as with other wire diameters, the actual amount of material removed by the 0.005-in. diameter wire brush was much less because this brush did not dig into the soft portions of the wood or comb the surface.

Little difference was noted in the results obtained with the knot-type brush and those with the solid-fill brush. Insufficient tests were made to draw any definite conclusions on the efficiency of the two brushes but the solid-wire brush did not cut deep grooves and left the surface much smoother.

Insufficient tests were run to conclude definitely that higher rotational speed of the brush increases the amount of surface removal; however, comparison between BT-83 and BT-85 and also between BT-82 and BT-84 shows that a brush rotational speed of 1900 rpm gave 60 to 75 per cent more removal than a speed of 1600 rpm.

The effect of brush loading on surface removal varies with the linear speed of the Flaminator. With-grain samples BT-37 and BT-43 show a 45 per cent increase in surface removal by increasing the brush loading from 5 to 10 lb when the linear speed of the Flaminator was 0.08 ft/sec. On cross-grain samples BT-38 and BT-44 the increase was 52 per cent for brush loading from 5 to 10 lb. When the Flaminator was operated at 0.30 ft/sec increasing the brush loading from 5 to 35 lb increased the amount of surface removed very slightly.

From Tables 9 and 10 it will be observed that 50 to 70 per cent more surface was removed in cross-grain travel than in with-grain travel.

2.3 Flaminator Unit Tests

Wood samples similar to those used in the previous tests were given a combined flame and wire brush treatment with the Flaminator fitted with the oxy-propane burner and various type brushes. Operating conditions were chosen to produce a No. 3 char. The charring tests indicated that this degree of charring dehydrated the wood to a reasonable depth and that additional charring required an enormous increase in the heat output of the burner to overcome the insulating effect of the charred top layer. The burner was set at a 45° angle, 1/8 in. from the surface and the Flaminator was towed across the samples at a speed of 0.30 ft/sec. A propane consumption of 0.64 cfm/min was required to produce the No. 3 char.

The results of the unit tests are given in Table 11. Flame treating increased the effectiveness of the surface removal unit by a factor of 2 to 7 in the tests conducted. Surface removal with the 0.005-in. diameter wire brush was increased by a factor of 2 to 3 on with-grain samples (compare test runs UT-15 and UT-17, Table 11 with BT-92, Table 9). In cross-grain travel this same brush removed more material by a factor of 2 to 4 when preceded by the flame. (Compare test runs UT-16 and UT-17 with BT-93). Flame treating increased the effectiveness of the 0.0118-in. diameter wire brush by a factor of 5 in the with-grain tests and by a factor of 2 in the cross-grain tests. (Compare BT-100 with UT-21 and BT-101 with UT-22). The effectiveness of the 0.016-in. diameter wire brush was increased by a factor of 6 in the with-grain Flaminator test and by a factor of 2 in the cross-grain tests.

Insufficient data were obtained to draw any conclusion on the

TABLE 11 Flaminator Unit Tests Using an Oxy-Propane Burner 1/8 in. from the Surface

Run		Brush Type	Brush Speed Rotational (rpm)	Brush Speed Linear (ft/sec)	Loading (lb)	Gas Rate (CFM) Gas	Gas Rate (CFM) Oxygen	Heat Output (BTU/Hr)	Surface removed (in. x 10^{-3}) Min.	Max.	Avg
UT With Grain Travel	1	0.014 wire-solid	1900	0.14	25	0.63	1.90	95700	19	19	15
	2	0.014 wire-solid	1900	0.12	35	0.64	1.90	97200	15	28	21
	4	0.014 wire-solid	1500	0.12	35	0.64	1.90	97200	19	37	29
	6	0.014 wire-solid	1500	0.12	35	0.66	1.90	100300	11	21	12
	9	0.014 wire-solid	1500	0.30	35	0.66	1.90	100300	1	9	9
	11	0.014 wire-solid	1500	0.30	15	0.62	1.93	94200	5	15	10
	13	Sander	1500	0.30	15	0.64	1.93	97200	9	11	10
	15	0.005 wire-solid	1700	0.30	35	0.63	1.95	95700	7	11	10
	17	0.005 wire-solid	1700	0.30	35	0.63	1.95	95700	10	28	18
	19	0.005 wire-solid	1400	0.30	35	0.63	1.95	95700	10	18	15
	21	0.0118 wire-solid	1400	0.30	35	0.66	1.95	100300	3	12	5
	23	0.0118 wire-knot	1500	0.30	35	0.66	1.95	100300	5	6	5
	25	0.016 wire-knot	1500	0.30	35	0.66	1.95	100300	6	11	6
UT Cross Grain Travel	3	0.014 wire-solid	1900	0.12	35	0.64	1.90	97200	22	32	27
	5	0.014 wire-solid	1500	0.12	35	0.64	1.90	97200	15	23	21
	7	0.014 wire-solid	1500	0.12	35	0.66	1.90	100300	16	26	20
	8	0.014 wire-solid	1500	0.30	35	0.64	1.90	97200	3	13	11
	10	0.014 wire-solid	1500	0.30	35	0.64	1.90	97200	10	14	12
	12	0.014 wire-solid	1500	0.30	15	0.62	1.93	94200	6	12	7
	14	Sander	1500	0.30	15	0.64	1.93	97200	18	18	18
	16	0.005 wire-solid	1700	0.30	35	0.63	1.95	95700	7	9	8
	18	0.005 wire-solid	1700	0.30	35	0.63	1.95	95700	9	14	12
	20	0.005 wire-solid	1400	0.30	35	0.63	1.95	95700	4	12	7
	22	0.0118 wire-solid	1400	0.30	35	0.66	1.95	100300	6	8	7
	24	0.0118 wire-knot	1500	0.30	35	0.66	1.95	100300	14	23	20
	26	0.016 wire-knot	1500	0.30	35	0.66	1.95	100300	10	24	16

effect of brush rotational speed on flame treated surfaces; however this factor seems insignificant in comparison with such factors as linear speed and direction of travel relation to the wood grain. With-grain samples UT-4 and UT-6 showed an average removal of 0.029 and 0.012 in. respectively when operating at 0.12 ft/sec as compared to 0.009 and 0.010 in. on samples UT-9 and UT-11 when operating at 0.30 ft/sec. Cross-grain samples UT-5 and UT-7 showed a removal of 0.021 and 0.020 in. respectively when the Flaminator operated at 0.12 ft/sec as compared to 0.011 and 0.012 in. on samples UT-8 and UT-10 when the speed was 0.30 ft/sec.

2.4 Recapitulation of Essential Features of the Flaminator

The foregoing tests indicated that the Flaminator can be developed into a practical flame treating unit for field scale operations. The vacuum on the collecting hood should be applied at the rear of the burner compartment and close to the surface being treated, thus drawing the flame along the surface. The brush should be separated from the burner by a distance sufficient to avoid damaging the brush.

The oxy-propane burner was the best of the high temperature burners tested and was most effective when mounted 1/8 in. above the surface at a 45° angle in a direction opposite that of the travel of the Flaminator. The linear speed of the Flaminator should be between 0.15 and 0.30 ft/sec and the burner adjusted to give charring equivalent to the No. 3 charring index.

Wire brushes made of wire having 0.010- to 0.016-in. diameters were most effective in removing wood surfaces. Wires of smaller diameters were ineffective and larger ones cut the surfaces badly. The rotational speed of the brushes should be about 1500 rpm.

Flame treatment increased the effectiveness of surface removal with a wire brush by a factor of 2 to 7. In all instances the greater surface removal occurred when the unit was operated cross-grain.

3. Airborne Hazard in Flame Treating Radioactively Contaminated Surfaces

Before proceeding with the construction of a field scale Flaminator it was necessary to consider the possibility of an airborne hazard being created by flame treating radioactively contaminated surfaces. Tests were conducted to determine the amount of radioactive material volatilized by passing a high temperature, high velocity flame over contaminated samples. In the investigation the burner was passed over twenty contaminated samples and the smoke particles and volatilized materials were collected on filter papers.

3.1 Contamination of Samples

Four methods were employed in the contamination of the test samples with a sea water contaminant containing mixed fission products.

Method A - The samples were held vertically in a spray booth and sprayed for 2 sec with contaminated sea water*. The samples were force dried in a vertical position in the spray booth dryer.

Method B - The samples were contaminated with 1.1 millicuries of solution by pipetting about 100 drops over their surfaces. The isotopic mixture and proportions were the same as Method A. The samples were in a horizontal position when contaminated and remained so while they dried in air.

*The fission product mixture was composed of Sr^{90}-Y^{90}, Zr^{95}, and Nb^{95}, assayed at 4 microcuries/ml, mixed in 100 ml of sea water. The proportions of these isotopes were: Sr^{90} and Y^{90}-35%, Y^{91}-15%, Zr^{95} and Nb^{95}-15%.

Method C - The samples were held in a horizontal plane in the spray booth and sprayed from above. The spraying time was 4 sec/ sample. The contaminant was a mixture of Sr^{90}-Y^{90} in sea water, which resulted in a solution activity of 0.6 microcuries/ml. The samples were dried for 1/2 hr while in the horizontal position in the spray booth dryer.

Method D - The samples were contaminated by dipping them face down in a shallow tray of contaminated solution. This solution was the same as used in Method C. The samples were placed in 1/8 to 1/4 in. of this solution and allowed to soak for a 30-sec period, face down. This soaking was followed by a 30-sec drain period, face up, and then the samples were dried for 30 min, face up, in the spray booth dryer.

3.2 Flame Treatment

The samples were flame-treated in a vacuum hood connected to a U. S. Air Force Turbo-super Compressor Collector Unit using a 12 in. by 13 in. Type H-60 filter paper to collect the contaminated smoke. The air flow-rate through the unit, with the filter paper in place, was 100 cfm and was sufficient to draw the contaminated aerosols generated inside the vacuum hood through the filter paper[2]. Three methods of flame treating were used.

Method X - The samples were treated with an acetylene air-induced burner (No. 11, Table 1). The burner produced a 2-in. wide flame which was oscillated across the sample at a linear rate of 4 or 5 ft/min.

Method Y - Treated with a 4-in. ribbon oxy-propane burner (No. 10, Table 1) at a linear rate of approximately 4 to 5 ft/min.

Method Z - Treated with a propane air-induced torch or burner (No. 11, Table 1). This torch was used with an oscillating motion as in Method X. The samples were counted (monitored) on a laboratory type scaler with a 12 in. by 12 in. gas flow proportional probe. A distance of 1/2 in. between probe window and sample was maintained with suitable spacers. Each sample, standard, and background were counted three times. Filter papers with an aluminum sheet metal backing were counted in the same manner. A blank (uncontaminated) sheet of filter paper was counted for background. Air samples taken at the exhaust of the turbo-compressor during each burner operation showed that all of the contamination was being collected on the filter paper.

3.3 Test Results

The results of the airborne hazard tests are given in Table 12. The table shows that for uniformity and ease of operation the dip method of contaminating samples (Method D) was far superior to the spray or drop methods. The spray method was unsatisfactory because the deposit of large droplets of contaminant made it difficult to obtain reproducible results. The drop method produced a series of very "hot" spots over the sample area, and was very time consuming. The dip method, where the samples were contaminated by placing them face down in an open tray because it produced uniform results, gave a higher contamination rate, required no special apparatus, and required less radioactive solution than the other methods. Table 12 shows that various woods retained different amounts of liquid contaminant. In decreasing order, the contaminant retention of the woods was pine, fir, oak, and teak, with pine retaining roughly twice as much of the contaminant

TABLE 12 Airborne Hazard Evaluation

Sample	Material	Sample Size (in.)	Procedure: Contamination	Procedure: Flame Treating	Initial Count(a) (c/m x 10^{-6})	Filter Paper Count (c/m x 10^{-4})	Contaminant Retained on Paper (%)
HT 1	Fir	12x12x2	A	X	6.84	2.19	0.32
2	Teak		A	X	5.60	15.9	2.84
3	Concrete		B	X	45.6(b)	85.3	1.87
4	Asphalt		B	X	48.4(b)	292.	6.03
5	Fir	12x3-5/8 x1-5/8	C	Y	2.35	1.11	0.47
6	Teak		C	Y	2.05	2.93	1.43
7	Pine		C	Y	3.28	16.75	5.1(c)
8	Oak		C	Y	1.62	1.13	0.70
9	Oak		D	Z	0.77	0.05	0.05
10	Fir		D	Z	1.21	0.74	0.61
11	Pine		D	Z	1.08	0.09	0.08
12	Teak		D	Z	0.74	1.00	1.35
13	Pine		D	Z	5.20	2.23	0.43
14	Fir		D	Z	4.20	3.17	0.76
15	Oak		D	Z	3.34	1.51	0.45
16	Teak		D	Z	2.90	4.42	1.52
17	Teak		D	Z	2.15	2.48	1.15
18	Pine		D	Z	4.92	0.53	0.11
19	Fir		D	Z	3.00	0.82	0.27
20	Oak		D	Z	2.50	0.14	0.06

(a) All counting data are averaged from three values which included the background count.

(b) These samples were only measureable on the rate meter. Their units are micro amps.

(c) Fire inside hood caused additional contamination to be collected on filter paper.

as did teak.

In all cases, only a small percentage of the radioactive contaminant from the sample became airborne by the action of the flames. Table 12 shows that the maximum caught on the filter papers was 6.03 per cent and the minimum was 0.05 per cent. The amount of contaminant removed from the wood samples by the flame decreased from teak to fir, pine, and oak. In several cases over ten times more contaminant was removed from the teak than from the pine or oak. It is believed that this difference in removal was a function of the presence of volatile oils or resins which were easily driven off when the wood was heated (teak is an "oily" wood). Similarly it was found that more contaminant was evidently carried off with the volatilized oils and smoke from the asphalt. In general, it appears that regardless of the material, more contaminant will be carried off by "oily" or easily volatilized surface materials, and furthermore the volatility of the surface material (which acts as a carrier), and not the radioactive contaminant, is the determining factor.

These tests indicate that the magnitude of the radiological airborne hazard is not as great as was anticipated. However, since airborne material was detected it may be assumed that the radiological airborne hazard will increase with higher specific surface activities.

4. The Field Model Flaminator

This Flaminator is an experimental field model designed for use on wood, asphalt and concrete surfaces. Its design was based on the experience gained from the laboratory Flaminator already described.

The field model employs oxygen-propane burners, various surface removal tools and a vacuum pick-up unit to collect dust and particulate matter removed from the surface. Standard equipment was used wherever possible in the experimental field model to expedite its construction and to reduce the cost of the unit.

The unit was designed for the use of four types of surface removal tools. These types were (1) wire brush for wood and concrete, (2) Tennant Revo-tool for wood and concrete, (3) sander for wood and, (4) scraper for asphalt surfaces.

4.1 Design Details

The principal components of the field model Flaminator are the chassis, burners, surface removal tools and the vacuum pick-up assembly.

4.1.1 Chassis

A Buda Chore Boy, Model FH, (Fig. 9) formed the chassis for the experimental field model Flaminator. This vehicle has a load capacity of 2,000 lb and a total deck area of 20 sq ft. It is powered by a 10-hp gasoline engine through a double-cone clutch which permits forward and reverse travel. A 20 to 1 gear reducer and a No. 4 dry-type Pullmore clutch were mounted on the vehicle to permit two speeds, an operating speed of 10 to 24 ft/min and a maneuvering speed of 5 to 10 mph.

4.1.2 Burners

The oxy-propane burners (Fig. 10) were made by reboring standard oxy-acetylene descaling nozzles as described in the laboratory Flaminator section. Five such nozzles were used, 3 standard 6-in. segments and 2 standard 4-in. segments, to produce an over-all flame width of 28 in.

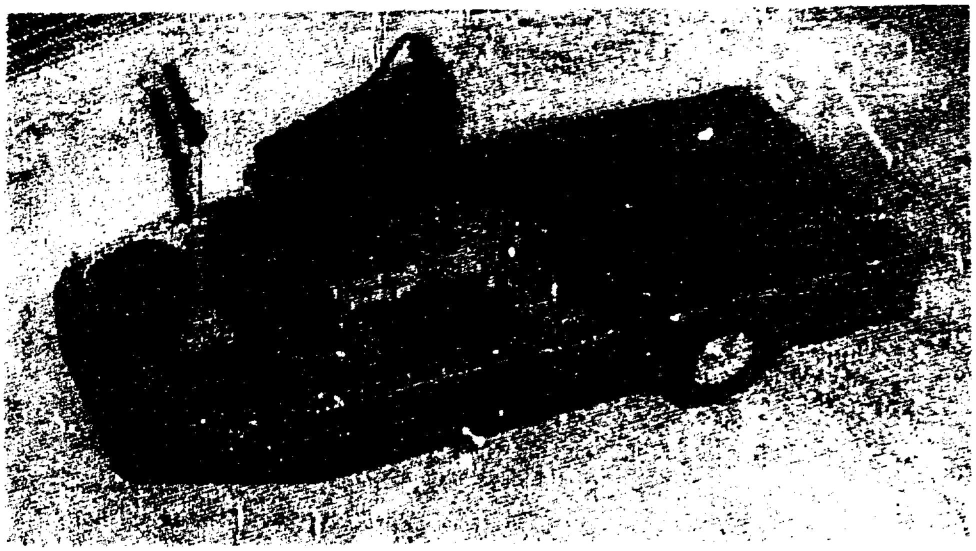


Fig. 9 Field Model Flaminator Chassis - Buda Chore Boy

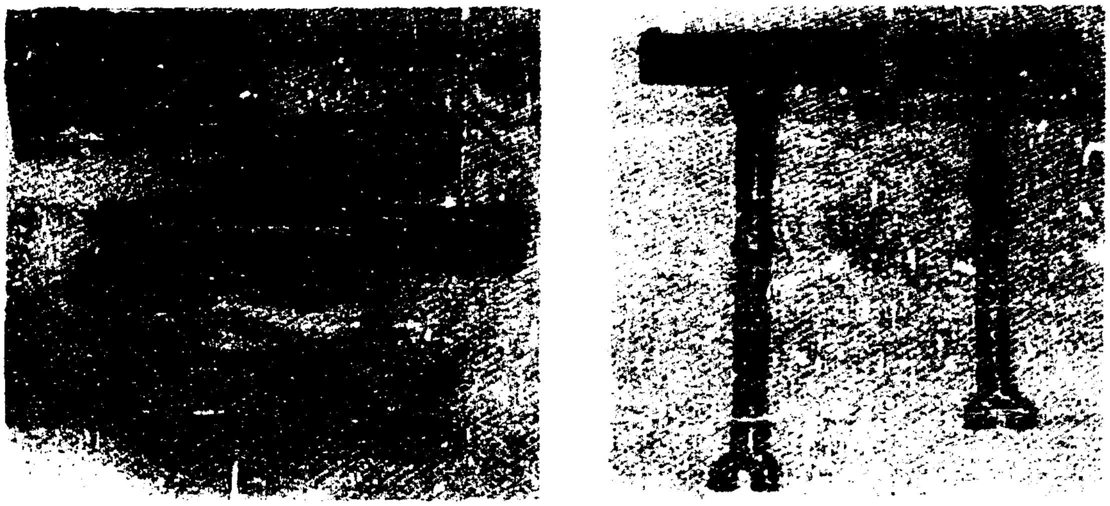


Fig. 10 Flaminator Burner - 4 in. and 6 in. Oxy-Propane Descaling Nozzles

Standard oxy-acetylene mixers and fittings were used. The burners were mounted on individual sleeve bearings on a common shaft which permitted each burner to pivot when it was used on irregular surfaces. A stainless steel hood was mounted over the burners to confine the flame and heat to the surface being treated. This hood was also pivoted on the burner shaft and the complete unit (burners and hood) was mounted under the chassis as shown in Fig. 11. A cable-controlled cam was provided to raise the burner and hood unit when it was not in use.

The burners were ignited with a remote control spark igniter.

Exhaust fumes from the burners were discharged approximately 4 ft above the operator's head through a 3-in. flexible hose and rigid tube.

4.1.3 Surface Removal Tools

The power for driving the four types of surface removal tools was furnished by a 2-cylinder 4-cycle air-cooled, Model TF Wisconsin engine which is rated at 9.9 hp at 1600 rpm and 12.6 hp at 2200 rpm. The engine was mounted on the chassis and the surface removal tools were connected through chain linkage. The position of the surface removal tools relative to that of the burner is shown in Fig. 12.

(a) Wire Brush

Three different wire brushes were used on the experimental field model Flaminator, a solid-fill type, a knot type and the Tennant These brushes are shown in Fig. 13. The solid-fill and knot type brushes consisted of an assembly of a sufficient number of standard buffing brushes on a 1 1/2-in. shaft to give the desired width of 28 in. A

*Manufactured by G. H. Tennant Co., for use on their floor refinishing machines.

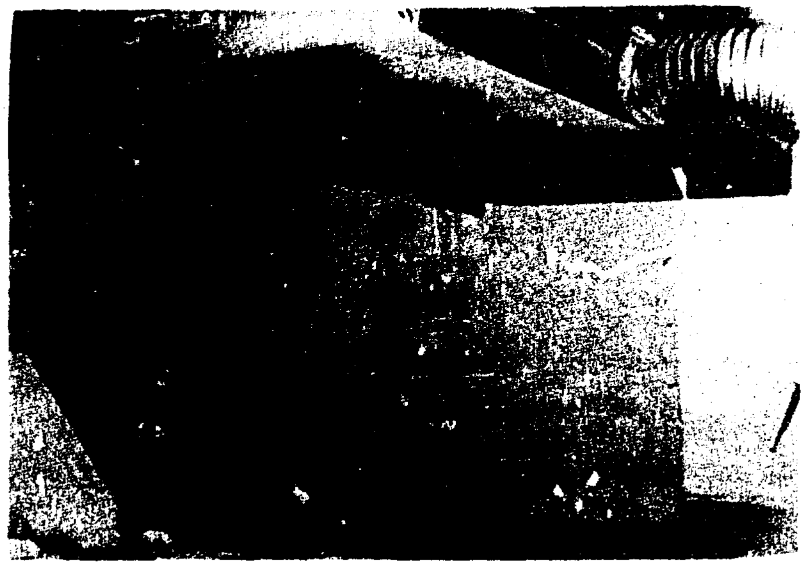


Fig. 11 Underneath View of Flaminator

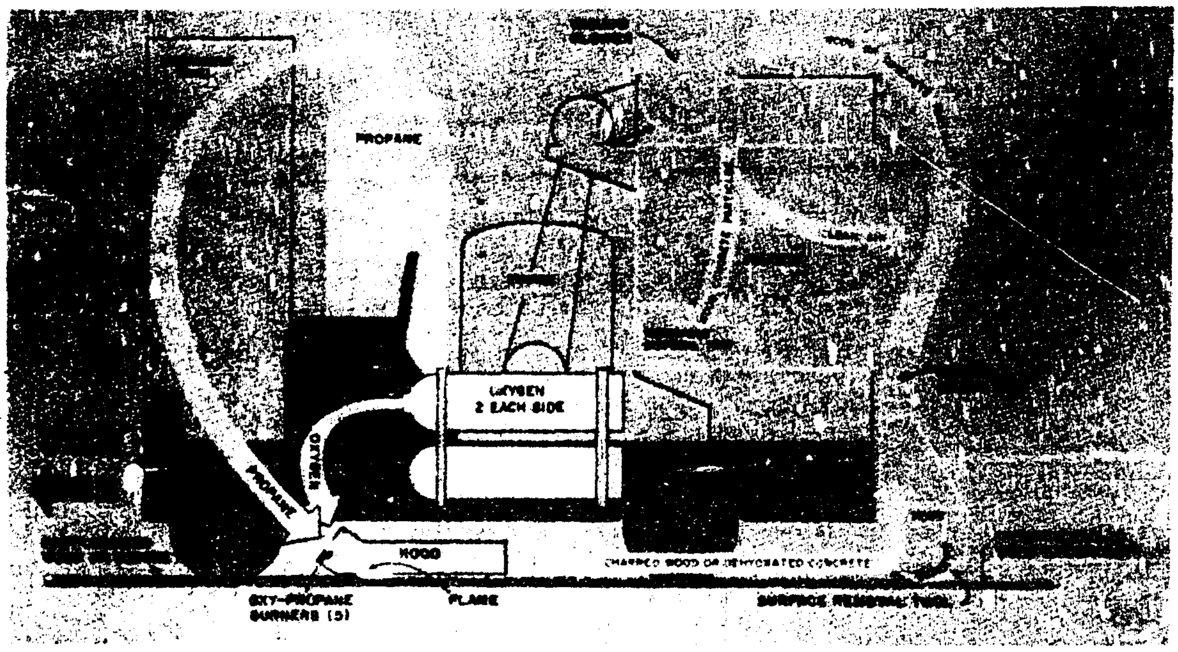
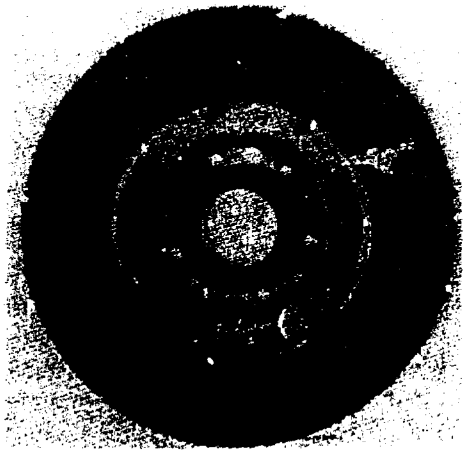
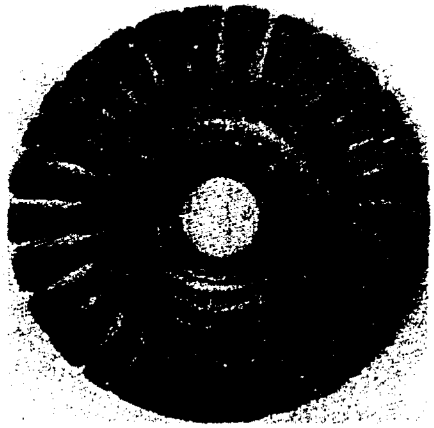


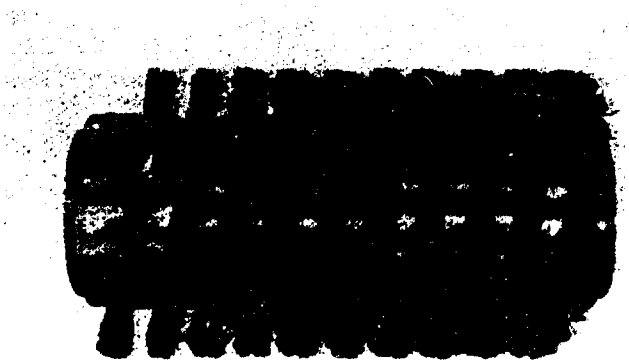
Fig. 12 Burner and Hood Assembly Mounted on Flaminator



a. Solid-Fill



b. Knot



c. Tennant

Fig. 13 Types of Wire Brushes Used with the Field Model Flaminator special adapter sleeve on this shaft was required for the Tennant Brush which was only 15 in. wide.

(b) Revo Tools

The Revo-tools are manufactured by the G. H. Tennant Company for use on a floor resurfacing machine. They are 8 in. in diameter and 15 in. long. The cutting wheels, approximately 2 in. in diameter, fit loosely on the shafts and as the entire assembly rotates, the cutters spin and bounce to give a cutting and pounding action. These Revo-tools are made with three types of cutters. The sharp No. 1 cutter is designed for cutting either concrete or wood. The blunt No. 4 is for pulverizing work and the intermediate No. 9 is designed for general all-round work. The No. 1 and No. 4 cutters, shown in Fig. 14, were tested on both wood and concrete surfaces prior to the design of the Flaminator. It was decided to use the No. 4 because the cutting wheels on the No. 1 broke very readily on concrete surfaces. The Revo-tools fit on the same sleeve shaft as the Tennant wire brush.

(c) Sanding Drum

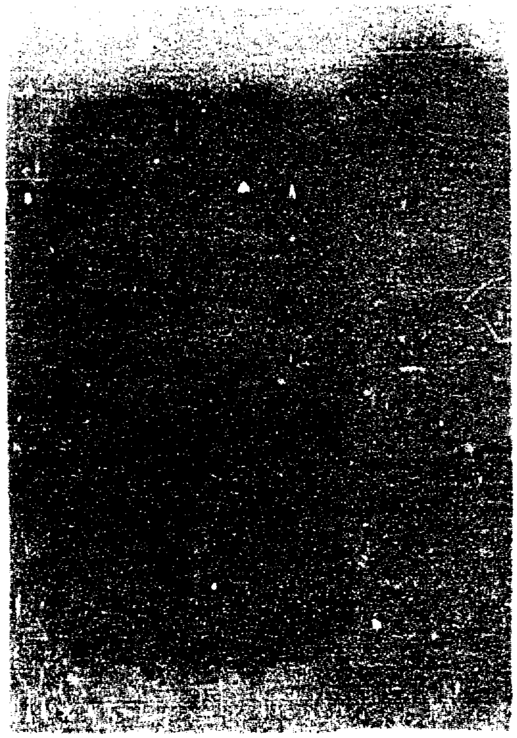
A Tennant sanding drum* was also used with the experimental field model Flaminator. The sanding drum was intended for use only on wood surfaces.

(d) Asphalt Scraper

An asphalt scraper was designed for use on flame softened asphaltic. This scraper attaches to the rear of the Flaminator after removal of the brush shaft and drive system.

*Manufactured by G. H. Tennant Co., for use on their floor refinishing machines.

No. 4 Cutter



No. 1 Cutter

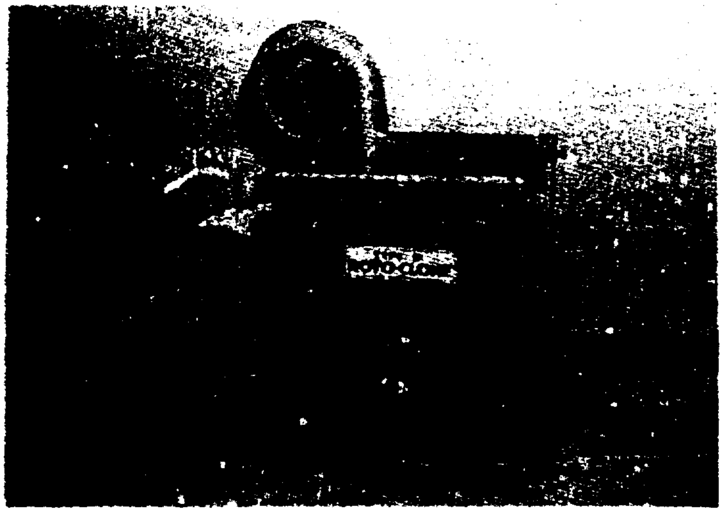
Fig. 14 Tennant Revo Tools

4.1.4 Vacuum Pick-up Assembly

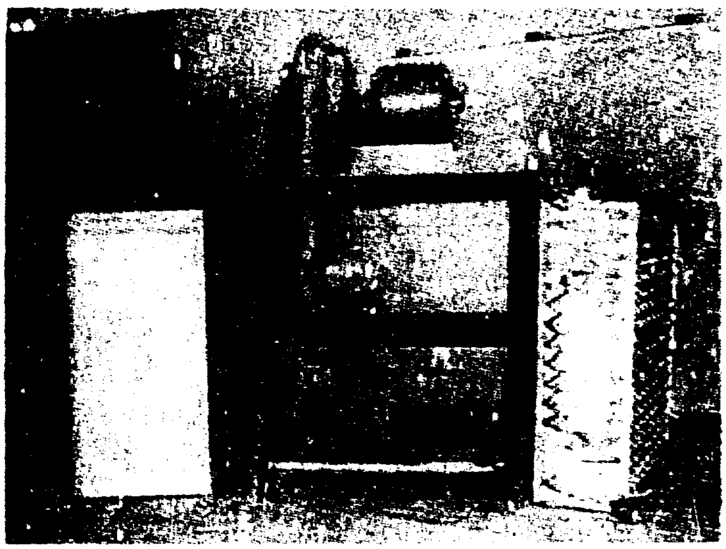
The American Air Filter, Model D, Rotoclone shown in Fig. 15 was used as the vacuum pick-up unit. This unit is designed to collect the waste material in a drawer (Fig. 15a) and to discharge clean air through the filter. Because the standard filter for this unit (Fig. 15b, right) was ineffective in removing airborne contaminant, the depth of the filter compartment was modified to accommodate a type M-6 Chemical Corps filter shown at the left of Fig. 15. The electric motor was removed from the air filter unit and modifications were made to drive the impeller at 5,200 rpm by a V-belt from the Wisconsin Engine. When operating at this speed the air filter had a capacity of 600 to 700 cfm and drew from 7 to 8 in. of water; however, when the engine was loaded by the surface removal tools, the blower speed was reduced to approximately 3,800 rpm. At this speed the air filter had a capacity of 500 to 600 cfm and drew from 4 to 6 in. of water. The blower is connected to the hood around the surface removal tools by a 5 in. flexible metal hose as shown in Fig. 16.

4.1.5 Control Instruments

The operation of the experimental field model Flaminator was controlled by instruments located on a panel near the operator as shown in Fig. 17. Levers for raising and lowering the burners and the surface removal tools were conveniently located at the right of the operator's seat. The control panel contained the following instruments: oxygen and propane pressure gauges, flowmeter for registering total flow of propane, solenoid valve switches for oxygen and propane, a spark igniter switch, pyrometers, Flaminator speed indicator, and such auxiliary engine instruments as tachometer, ammeters and starter switch.



a. Showing Drawer for Holding Waste



b. Showing Filters; Standard One at the Right, Chemical Corps M-6 at the Left

Fig. 15 Flaminator Vacuum Pick-up and Filter Unit

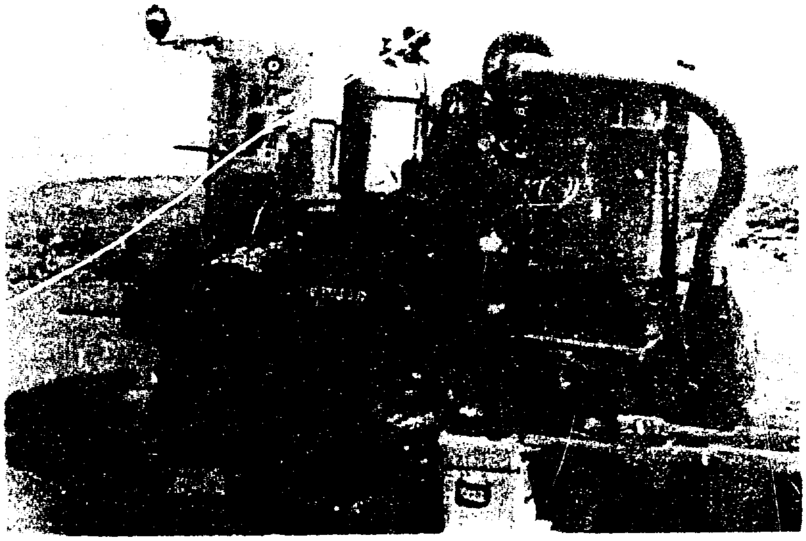


Fig. 16 Completed Flaminator - Control Panel and Propane Tank to Right of Operator, Oxygen Cylinders are Mounted on Each Side and the Vacuum Unit Behind the Operator

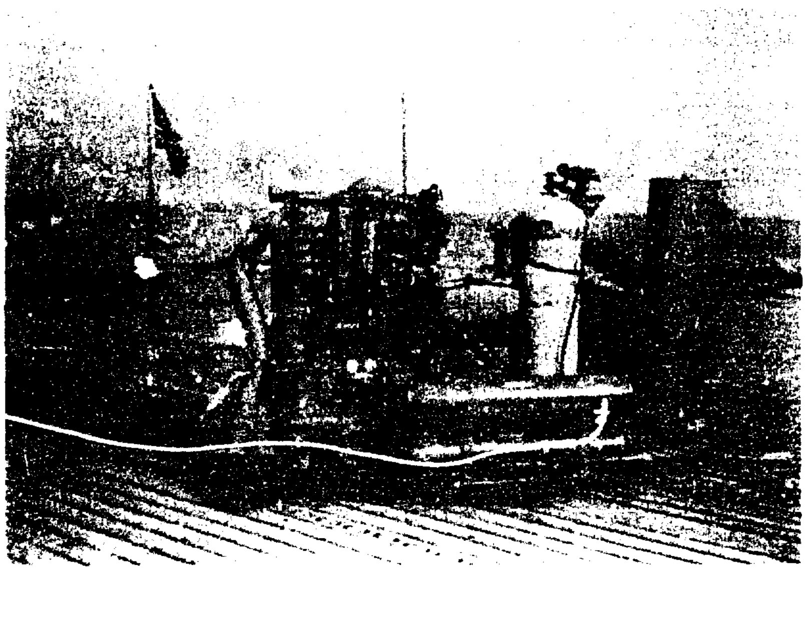


Fig. 17 Flaminator in Use on Aircraft Flight Deck

The oxygen and propane lines are connected to a manifold at the rear of the Flaminator (Fig. 17). Individual control valves are provided for regulating the gas flow to each of the burners. After adjusting the flow of oxygen and propane to the individual burners the operator can turn the burners on and off with the solenoid switches at the control panel.

Approved by:

E. R. Tompkins

E. R. TOMPKINS, Head
Chemical Technology Division

For the Scientific Director

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